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Description

Method for resource allocation in a radio communication system

The invention relates to a method for resource allocation in a radio communications system, and to a radio communications system designed in such a way.

WO 98/08353 A2 describes a mobile radio system in which a number of base stations, which each form a radio cell, are each allocated to one base station controller. Base stations in the boundary area between the regions of two base station controllers can optionally be controlled by each of these controllers.

Messages (for example voice, video information or other data) are transmitted via a radio interface by means of electromagnetic waves in radio communications systems. The radio interface relates to a connection between a base station and subscriber stations, in which case the subscriber stations may be mobile stations or stationary radio stations.

Radio communications systems are generally of cellular design, in order to allow mobile subscribers to have access to different supply regions, which are referred to as radio cells. Only a limited number of resources are available in radio communications systems since the radio interface in each radio cell has a relatively narrow bandwidth in comparison to a landline network, and these resources may differ, depending on the chosen multiplexing method, in frequency, timing and, in the case of code-division multiplexing, in their signal form, and they each provide a specific transmission rate.

services for the individual subscriber stations. To do this, the available resources and their allocation to specific connections must be managed in each radio cell.

In addition, interaction between adjacent base stations (NodeB) and base station controllers (RNC) is required in cellular radio communications systems, in order to prevent multiple allocation of resources, and hence unnecessary interference. This results in a considerable amount of signaling complexity in the radio communications system.

According to the previous UTRAN system architecture (Universal Telecommunications Radio Access Network), in this context see Tdoc SMG2 512/98, ETSI STC SMG2 #28, Dresden, November 16, 1998, the problem is solved or circumvented by the possible dynamic for resource allocation being deliberately restricted. To do this, the base station controller allocates exclusively to each connection as many dedicated channels (DCH) as are required for transmission of the peak value of the data rate for real time services (RT).

If the allocated RT capacity is not all required at certain periods owing to variable data rates, it is admittedly possible for services which are not real time services (non-real-time or NRT services) to transmit packets in addition. However, it is impossible to transmit data from other subscriber stations. The allocation (scheduling) of the resources for the services to the DCH of a subscriber station is carried out by an entity for resource monitoring, which is referred to as the dedicated Medium Access Control (MAC-d), specifically for each subscriber station. No direct interaction between different MAC-d entities is envisaged.

Furthermore, it is possible to transmit NRT services in a common channel in the downlink direction (Downlink

Shared Channel DSCH). These are resources, which are managed by a common entity of the shared MAC (MAC-sh), in each cell, which can be temporarily allocated to different subscriber stations for specific frame periods. The MAC-sh is set up on a cell-specific basis, and no direct interaction between different MAC-sh entities is envisaged.

The logical separation of DCHs and DSCHs leads to the following disadvantages owing to the involvement of a number of MAC entities, which are in general physically separated from one another in different base station controllers and can therefore communicate with one another only with considerable signaling complexity.

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While, in the case of exclusive transmission by DCH, all the codes for CDMA radio transmission (CDMA code division multiple access) can be used optimally by adaptive data compression, this advantage is partially lost when DSCH is used, since individual services cannot be shared between DCH and DSCH with an acceptable level of complexity, and a rate matching process is carried out separately for DCH and DSCH. Thus, in general, more transmission capacity (that is to say more resources) is required overall for one subscriber station than would be possible if all the services were multiplexed into one data stream.

Since the DSCH must have a high transmission capacity for effective use, and a large amount of resources are therefore reserved exclusively for it, this is, however, suitable only for transmitting NRT services, this can prevent approval for new connections for RT services (hard blocking).

Owing to the necessary DCH allocation corresponding to the maximum data rate for all the RT services for a subscriber station, ~~hard blocking can occur even though a large number of allocated resources are not required~~

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hard blocking can occur even though a large number of allocated resources are not required for transmission all the time when variable data rates are used.

The signaling of a data transmission in the DSCH for a specific subscriber station by means of the TFCI parameter (TFCI Transport Format Combination Indicator) in the associated DCH is cumbersome and, furthermore, reduces the maximum number of transport format combinations (TFC Transport Format Combination) which can be transmitted in the TFCI, since TFCI bits must be reserved exclusively for the DSCH.

The soft handover service feature, which considerably increases the transmission reliability and can result in a reduction in the overall interference in WCDMA systems (wideband CDMA), is not available with the current DSCH concept. For a soft handover, one subscriber station is temporarily supplied from at least two base stations.

The interaction of said factors when transmitting services with variable data rates allows the possible capacity of the radio interface to be used only to a limited extent.

The invention is thus based on the object of improving the radio resource management in radio communications systems. This object is achieved by the method having the features of claim 1, and by the radio communications system having the features of claim 14. Advantageous developments are described in the dependent claims.

In the following text, the resources are referred to as channels, in which case, depending on the chosen multiplexing method, a channel is characterized by a frequency band and/or a timeslot and/or a code and/or other separation options.

A number of base stations in a radio communications system are normally controlled by one base station controller in each case, with regard to resource allocation. However, one base station provides only a limited number of channels, which can be allocated to connections from and to different subscriber stations.

According to the invention, some of the channels which can be provided by the base stations are used for exclusive monitoring of the associated base station controller, with the intention of a second base station controller being able to use them dynamically, without further agreement by the base station controller. The number of channels in this portion can be varied, with the involvement of the second base station controller. The reservation of channels for the second base station controller reduces the signaling complexity. The change to the portion of the channels which are used for exclusive monitoring of the associated base station controller is not carried out on a frame-by-frame basis but as required, that is to say generally at relatively long time intervals.

The previous subscriber-related reservation of resources in adjacent cells by the base station controller is thus replaced by resource reservation which is related to the area (RNS - Radio Network Subsystem) monitored by the respective adjacent base station controllers (RNC). The direct monitoring of a specific proportion of the transmission capacity in its own cells is transmitted to the adjacent RNC. This approach satisfies the precondition to allow the MAC-d entities in each RNC to manage the resources monitored by them dynamically. It is thus not only possible to support the soft combining service feature but also to avoid the interference between cells which belong to different RNC areas during non-orthogonal resource allocation.

The method according to the invention also avoids the need for time-consuming checking with the adjacent RNCs on each occasion before allocation of a resource. This reservation of resources in adjacent cells is not only worthwhile in order to allow a soft handover in the downlink direction for W-CDMA, but also to avoid undesirable interference between the radio cells in TD-CDMA (time division CDMA).

According to one advantageous refinement of the invention, the number of channels which are assigned to the second RNC is matched cyclically to the traffic volume. This is done by signaling between the RNCs. This signaling complexity is considerably less than for continuous subscriber-related resource sharing between the RNS areas. The sharing of capacity is thus optimized, and the risk of hard blocking by signaling and prior reservation between the RNCs involved is kept low.

According to a further refinement of the invention, the RNC carries out subscriber-related allocation of the channels, in which case one channel can also be allocated to a number of subscriber stations. Only one entity may be set up for each subscriber station in the RNC. The logical separation between DCH and DSCH is cancelled in the MAC layer. There is now only one dedicated MAC entity in the RNC for each subscriber station, and this can access all the resources which have been released by the RNC for data transmission by the corresponding subscriber station. In principle, each resource can be allocated to a number of subscriber stations in order to avoid unused resources for services whose data rates are variable.

The allocation of channels is advantageously dynamically adapted from timeslot to timeslot. The method according to the invention thus relates to completely dynamic allocation of resources and does not involve the otherwise high level of signaling

complexity. It must be possible to switch a channel very quickly between different subscriber stations after each transmission frame (approximately every 10 ms for UTRAN) since the data rates generally change dynamically, in order to avoid unused resources and hence to maximize the spectral efficiency.

A further refinement provides for the subscriber-related entities of the individual subscriber stations to interact in the RNC. This optimizes access to the available resources within an RNC. The subscriber-related MAC-d entities to this end communicate via cell-related tables, in which the allocation of the available resources to the subscriber stations located in the radio cell is continuously updated. Multiple allocations are avoided by the communication between the subscriber-related MAC-d entities.

The allocation of priorities for the individual subscriber stations when allocating resources makes it possible to guarantee qualities of service for RT services, while nevertheless optimally using all the resources. When priorities are equal, the use of the channel is governed by dynamic prioritization on the basis of the transmission situation, or the time sequence of a resource request.

Resource tables (Shared Channel Table SCT) are advantageously set up for resource management and indicate, for all channels, which priority is allocated to which subscriber stations for that channel, and which subscriber station is currently using that channel. A table is set up in the RNC for each cell in which subscriber stations are located and which are managed by the RNC. This table in each case controls the resources in a radio cell which are monitored by that RNC. The table ensures that none of these resources is used by a number of MAC-d entities at the same time. The entries in the table are adapted dynamically with regard to allocation. While a

connection is in existence, dynamic resource allocation is carried out in such a manner that each MAC-d entity requests appropriate resources, depending on the amount of data to be transmitted at that time for its subscriber station, with the SCTs on those radio cells which are involved in the connection (only ever one radio cell without a soft handover).

It is thus also possible to allocate resources which are as orthogonal as possible to the various base stations within the supply area of an RNC when using a TDMA-based transmission method (time division multiple access). This minimizes the interference between the radio cells.

The free capacity which can still be used in each resource is determined in each RNC by statistical evaluation of the SCT utilization. This is used to allocate a specific subset of the available resources with appropriate priorities to the new subscriber stations as optimally as possible when setting up new connections and, from this and in combination with the data rates of the services to be transmitted, to determine the required transport format combinations.

If a subscriber station requires a handover to a radio cell whose resources cannot be accessed by the RNC (SRNC) responsible for that subscriber station, since no adequate reservation has been made or can be made, the SRNC functionality is relocated (SRNC relocation).

An exemplary embodiment of the invention will be explained in more detail with reference to the attached drawings, in which:

Figure 1 shows a radio communications system,

Figures 2, 3 show a cellular breakdown of the radio supply region into different RNS areas for W-CDMA and TD-CDMA, respectively,

Figure 4 shows the channel allocation for soft handover with W-CDMA,

Figures 5, 6 show a channel allocation for W-CDMA and TD-CDMA, respectively,

Figure 7 shows the use of a table for channel allocation in the RNC, and

Figures 8, 9 show one form of signaling for an inter-RNC soft handover.

The mobile radio system illustrated in Figure 1 as an example of a radio communications system comprises a large number of mobile switching centers MSC which are networked to one another and produce access to a landline network PSTN. Furthermore, each of these mobile switching centers MSC is connected to at least one base station controller RNC for controlling the base stations BS and for allocating radio resources. Each of these base station controllers RNC in turn allows a connection to at least one base station BS. However, the base station controllers RNC can also be networked with one another as shown in Figure 8.

A base station BS can use a radio interface to set up a connection to a subscriber station, for example mobile stations MS or other mobile and stationary terminals. At least one radio cell is formed by each base station BS.

By way of example, Figure 1 shows connections V1, V2, V3 for transmitting user information ni and signaling information si as point-to-point links between subscriber stations MS and a base station BS.

An operation and maintenance center OMC provides monitoring and maintenance functions for the mobile radio system, or for parts of it. The functionality of

this structure can be transferred to other radio communications systems in which the invention can be used, in particular for subscriber access networks with wire-free subscriber access, and for base stations and subscriber stations operating in the unlicensed frequency band.

The invention will be explained in the following text with reference to two different radio interfaces, to be precise for a W-CDMA radio interface using the FDD mode (frequency division duplex) and for a TD-CDMA radio interface using the TDD mode (time division duplex). Further details of radio communications systems with such radio interfaces can be found, for example, in DE 198 35 643 and DE 198 20 736.

Figure 2 shows a cellular radio communications system having a W-CDMA radio interface and comprising a large number of radio cells. One radio cell is in this case supplied from one base station BS, with the radio cells of a number of base stations BS forming an area RNS (radio network subsystem) which is in each case monitored by one base station controller RNC. Six channels are provided, for example, as radio resources for supplying the subscriber stations MS in each of the radio cells. The channels are formed by means of a spread code, see Figure 5, and a frequency band (bandwidth 5 MHz). Some of the channels in each radio cell are intended for allocation by that particular base station controller RNC, while others of the channels are reserved for adjacent areas RNS and can be allocated by the responsible base station controllers RNC there.

In the center of an area, for example RNS1, all the channels can be made available to that area without any reservations being made for adjacent RNSs. The number of reserved channels, that is to say the transmission capacity which has been reserved for management by adjacent base station controllers RNC, can be variable

in the individual radio cells and can be set as required. This is done by means of a signaling interchange between the base station controllers RNC, thus corresponding to the varying amount of traffic. However, the signaling complexity is considerably less than for subscriber-related reservation.

The channels in a radio cell are also subdivided in a radio communications system having a TD-CDMA radio interface as shown in Figure 3. Some of the channels can be allocated by the base station controller RNC of the radio cell without any restriction, while others are subject to allocation restrictions, in order to limit the interference for adjacent cells. The restriction occurs in particular at the edges of an RNS area, since the RNC has no information about the channel allocation in the adjacent RNS.

Further particular channels are allocated to an adjacent RNS. In this case as well, some of the channels are subjected to exclusive monitoring by the base station controller RNC which controls the base station BS for the radio cell. Some of the channels can be allocated only by base station controllers RNCs of adjacent cells or after interference measurements in the channels. The capacity allocation to restricted, unrestricted, or no use (that is to say use by adjacent cells) can be varied depending on the traffic load at the time.

The same channels can also be reserved for restrictive use in adjacent RNSs. An interference measurement, which is carried out by the base stations BS or else with the assistance of measurements from subscriber stations MS, is used to determine whether the channel is already being used or is subject to excessive interference. If this is not the case, then the base station controller RNC allocates that channel without referring back to any other RNCs. Channels such as these are preferably used for NRT services, for which

an adequate quality of service can be guaranteed by repeated transmission or by other measures, even when reception is subject to interference at times.

Figure 4 shows the use of channels by subscriber stations MS1 to MS4 which are located in the supply area of different base stations BS, with the base stations BS being controlled by different base station controllers RNC. Some of the channels of an RNS which is monitored by an RNC1 to RNC3 are in each case reserved for the adjacent RNC or RNCs. As shown in Figure 4, the channels are subdivided into dedicated and shared channels DPC, SPC. The dedicated channels DPC are each allocated exclusively to one subscriber station MS, while the shared channels SPC can be used alternately by different subscriber stations MS. This means that it is possible to produce a better match to the different character of the services and the variable data rates. A subscriber station MS can in this case use dedicated and shared channels DPC, SPC at the same time, or else only one type of channel DPC, SPC (see also Figure 7).

If a subscriber station, for example MS2 or MS3, is located in the boundary area of an area RNS of a base station controller RNC, then the soft handover process can be used to produce a smooth handover by ensuring a simultaneous supply from different base stations BS. In this case, the subscriber station MS2, MS3 is supplied from base stations BS of different RNSs. The previous reservation of some of the channels for adjacent RNCs helps to ensure this double supply with little signaling complexity.

The nature of the channels for W-CDMA and TD-CDMA radio interfaces, respectively, will be explained with reference to Figures 5 and 6. Both cases are based on a broadband frequency band in which other multiplexing methods can be used for subscriber separation.

As shown in Figure 5, codes with different spread factors SF can be derived from a code tree, which is formed in accordance with DE 198 35 643. These codes can be shared between dedicated, shared and common channels DPC, SPC, CPC. The lower the spread factor SF, the higher is the data rate on that channel. The common channels CPC contain monitoring information (corresponding to BCCH, FACH, PCH) which is aimed at a number of subscriber stations MS, in the sense of a point-to-multipoint link.

As shown in Figure 6, the channel breakdown for TD-CDMA is as follows: one frame is, for example, subdivided into eight timeslots TS, in which case 16 channels in each timeslot TS1 to TS8 can be separated on the basis of their code 1 to 16. In TD-CDMA as well, channels can be subdivided into dedicated, shared and common channels DPC, SPC and CPC, with the channels being grouped, for example, on the basis of the timeslots. Further particular timeslots remain unused, since they have been assigned exclusively for allocation by an adjacent base station controller RNC. A subdivision into channels for unrestricted use and channels for restricted use can also be made both within the DPC and the SPC. The distinction is that channels are not allocated for restricted use until that channel has been checked. The process of measuring that channel, as has already been described, is carried out for this purpose. If the interference situation allows, the channel can then be assigned by the RNC for that radio cell.

Figure 7 shows a base station controller RNC via which the connections to subscriber stations MS1, MS2 to MSm have been set up. This base station controller SRNC is referred to as the serving RNC or else the anchor RNC, since it remains responsible to the other network devices (MSC etc.) for these connections for the duration of such a connection. If a subscriber station MS1 or MSm moves, during the connection, into the

monitored area of another RNC in which channels are reserved for it, which is referred to as a drift RNC (DRNC), then the SNRC can allocate channels from the reserved area by using the MAC-d entity which is responsible for the subscriber station MS to check with the SCT which is responsible for the new cell.

In the TDD transmission method, as an example for non-orthogonal resources in adjacent cells, matching complexity is also involved between the channel allocations of the individual radio cells in that particular RNS area, when adjacent radio cells are operated on the basis of time grouping in the same frequency band.

An entity MAC-d, in the sense of a process in the SRNC, is set up for each subscriber station MS, and this requests the radio resources for this subscriber station MS for the duration of the connection. The table SCT (shared channel table) is used in order to allocate channels to the subscriber station MS and, for those channels which are available in a radio cell, indicates which subscriber station MS1 to MSm may use which channel SPC1 to SPCmax, and with what priority (Prio). Furthermore, the table SCT indicates which subscriber station MS is using the channel at that time (used). If there is no entry in a field, then this means that this channel is not available for that subscriber station MS, for example SPC2 for MS1.

The tabular form is in this case used only to illustrate a clear form of resource management, in which case a pointer can be used to access the individual entries quickly. Other forms of representation are also possible.

The priorities for the access rights to the channels are defined in accordance with the requirements of RT or NRT services and the quality of service. This is an unchanging priority, which need not be varied

continuously. The unchanging prioritization of the subscriber stations MS and services in the table SCT can be adapted if the service combination or the services of a subscriber station MS change. The prioritization is carried out within the responsible RNC.

In the case of packet services for example, a dynamic priority, which is used within a group of subscriber stations MS having the same unchanging priority, can also be influenced by the following variables:

- subscriber station with a large number of temporarily stored data packet have high priority,
- data packets with a short maximum permissible delay time have a high priority, with the delay at that time also being taken into account if appropriate,
- subscriber stations with data packets which need to be transmitted repeatedly have a high priority.

The dynamic priority can be used to decide the channel allocation from frame to frame.

If one channel is allocated to a number of subscriber stations MS, then the subsequent allocation of the channel is governed by the highest unchanging priority. If the unchanging priority is the same for a number of subscriber stations, then the priority is governed by the higher dynamic priority. If even this does not result in any difference, then the previous allocation remains unchanged. This decision on the specific channel allocation is made from frame to frame, that is to say within 10 ms.

The prioritization process, in particular the unchanging priorities, allows the network operators to distinguish between services in order to offer services matched to specific market segments at appropriate prices.

In contrast to subscriber-related allocation of channels in adjacent RNSs, which would necessitate communication between the RNCs, the signaling complexity can be kept low if, according to the invention, channels of the adjacent RNS are always reserved for the RNC, and these channels can be made available without any checks.

Figure 7 shows the management process, just for the shared channels SPC. However, DPCs and SPCs do not require different treatment. Standard tables SCT can be set up for all types of channel DPC, SPC. Simply the joint management of all the resources in a radio cell overcomes a number of the disadvantages of using DPCs and SPCs that occur in the prior art. Synchronization of transmission for mixed use of DPCs and SPCs can be found in DE 198 57 041.

A subscriber station MS in Figure 8 is located in the boundary area of two radio cells (cell 1 and cell 2). However, these two radio cells are monitored by two different RNCs. The connection was originally set up in the SRNC, but the subscriber station MS is moving into the area RNS of the DRNC. The RNCs are connected to one another via an interface Iur. The two radio cells are formed by the base stations BS (often also referred to as NodeB) which are connected to the respective RNC via an interface Iub. The RNCs communicate via radio resource managers RRC (radio resource control), which handle the reservation of channels for adjacent RNCs.

Figure 9 shows, in simplified form, a method sequence for a soft handover corresponding to the illustration in Figure 8. Based on the situation in which the subscriber station MS has a connection to the cell 1, but requires that the active set of base stations BS involved in the connection be enlarged to include the cell 2, the method steps carried out are as follows.

In a first step (1), the device for radio resource management RRC in the SRNC reserves transmission capacity in cell 2 for the new subscriber station MS. If the channels available in cell 2 are not sufficient for the SRNC, a request is made to the RRC for the DRNS for the range of reserved channels to be enlarged.

In a second step (2), the RRC chooses from the SRNC the appropriate channels SPC or DPC in cell 2, and transmits the correspondingly calculated TFCS to both layer-1 entities and to the MAC-d entity for the base station BS supplying the subscriber station MS (the two TFCSs in the two cells may be different).

In a third step, the MAC-d entity receives available channels SPC and DPC in both cells during each frame interval by checking with the respective SCTs, and transmits the TFCI to both cells (the two TFCI parameters may be different). The nature of the signaling with TFCI can be found in DE 198 56 834.

After the handover to the cell 2 - the cell 1 no longer provides any channel for the subscriber station MS - the resource management responsible for the subscriber station MS at that time can also be handed over to the second RNC. The DRNC then becomes the SRNC. A handover becomes urgent when the previous DRNC cannot allocate channels in radio cells in which the subscriber station MS must be supplied.